Draft Quissett Harbor Embayment System Total Maximum Daily Loads For Total Nitrogen

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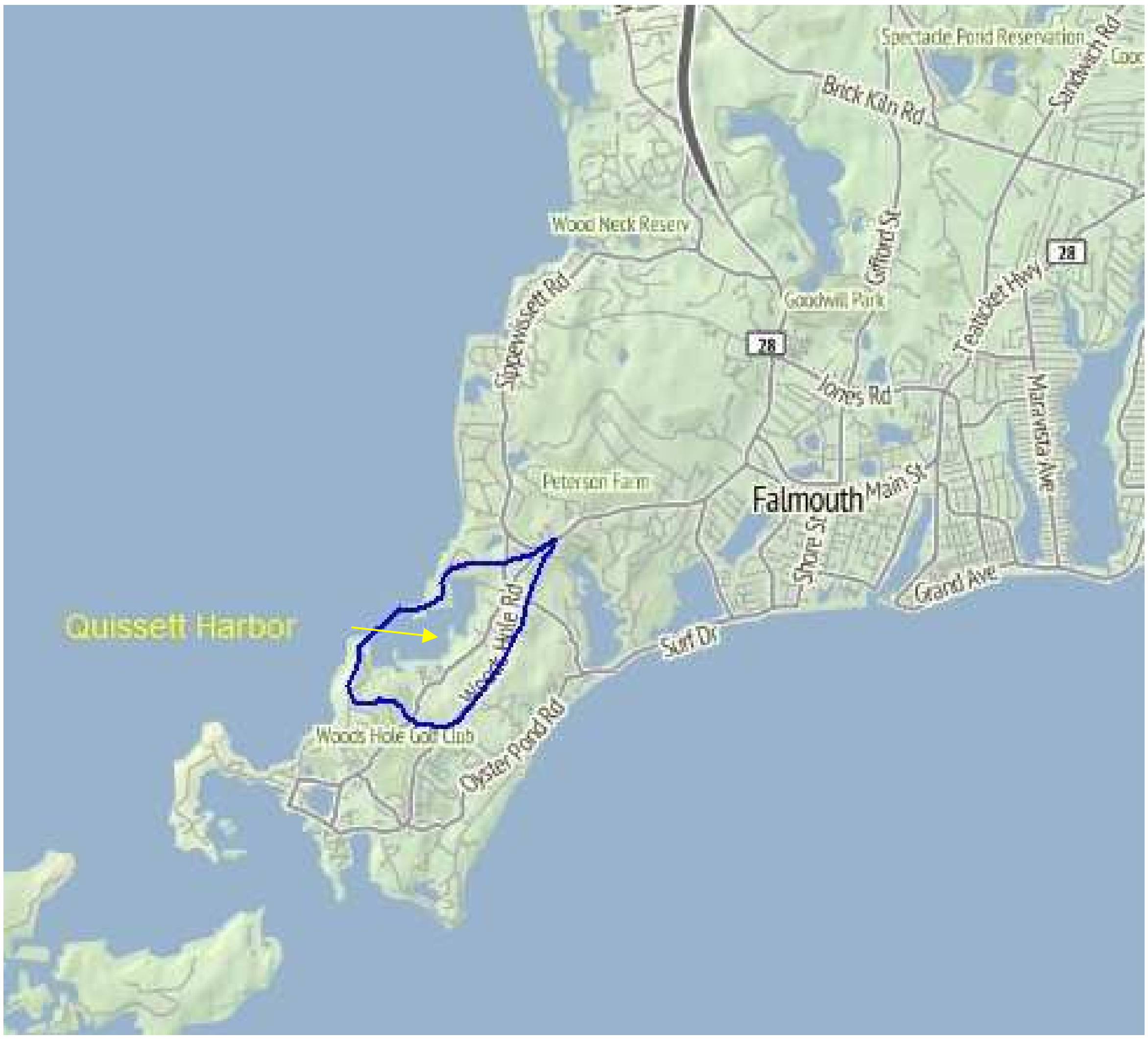


COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
MATTHEW BEATON, SECRETARY
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
MARTIN SUUBERG, COMMISSIONER
BUREAU OF WATER RESOURCES
DOUGLAS FINE, ASSISTANT COMMISSIONER

August 2017

Draft Quissett Harbor System
Total Maximum Daily Loads
For Total Nitrogen

Key Feature:	Total Nitrogen TMDL for Quissett Harbor
Location:	USEPA Region 1
Land Type:	New England Coastal
303d Listing:	Quissett Harbor was found to be impaired for nutrients during the development of this TMDL. Quissett Harbor (MA95-25) is on the Category 4a list for completed fecal coliform TMDL (EPA #36172).
Data Sources:	University of Massachusetts – Dartmouth/School for Marine Science and Technology; US Geological Survey; Applied Coastal Research and Engineering, Inc.; Cape Cod Commission, Town of Falmouth
Data Mechanism:	Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model
Monitoring Plan:	Buzzards Bay Coalition's Baywatcher Monitoring Program and Town of Falmouth with technical assistance by SMAST
Control Measures:	Sewering, Storm Water Management, Attenuation by Impoundments and Wetlands, Fertilizer Use By-laws

Title page map and map this page made via ggmap, courtesy Kahle and H. Wickham 2013

Executive Summary

Problem Statement

Excessive nitrogen (N) originating primarily from a wide range of sources has added to the impairment of the environmental quality of the Quissett Harbor Estuarine System. Excess nutrients have led to significant decreases in the environmental quality of coastal rivers, ponds, and harbors in many communities in southeastern Massachusetts. In the Town of Falmouth the problems in coastal waters include:

- Undesirable increases in macroalgae
- Loss of eelgrass beds, which are critical habitats for macroinvertebrates and fish
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life
- Reductions in the diversity of benthic animal populations
- Periodic algae blooms

With proper management of nitrogen inputs these trends can be reversed. Without proper management more severe problems might develop, including:

- Periodic fish kills
- Unpleasant odors and scum
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities

Coastal communities, including Falmouth, rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings will result in complete replacement of eelgrass by macro-algae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a complete loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of Quissett Harbor's coastal waters will be greatly reduced, and could cease altogether.

Sources of Nitrogen

Nitrogen enters the waters of coastal embayments from the following sources:

- The watershed
    - On-site subsurface wastewater disposal systems
    - Stormwater Runoff
    - Non-golf course and golf course fertilizers
    - Natural background
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments

Figure ES-A and Figure ES-B illustrate the percent contribution of all the sources of N and the controllable N sources to the estuary system, respectfully. Values are based on Table IV-3 and Figure IV-4 from the Massachusetts Estuaries Project (MEP) Technical Report. As evident, most of the present *controllable* load to this system comes from agriculture and septic systems.

Figure ES-A: Percent Contributions of All Watershed Nitrogen Sources to Quissett Harbor System

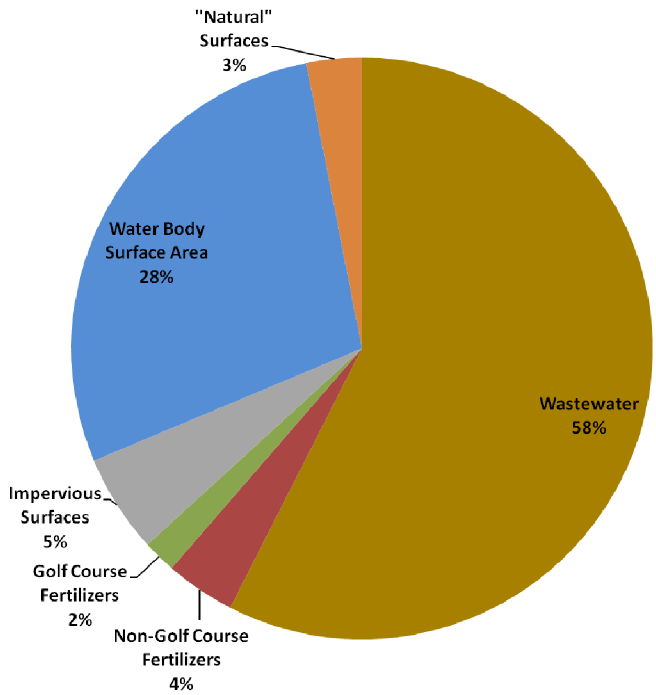
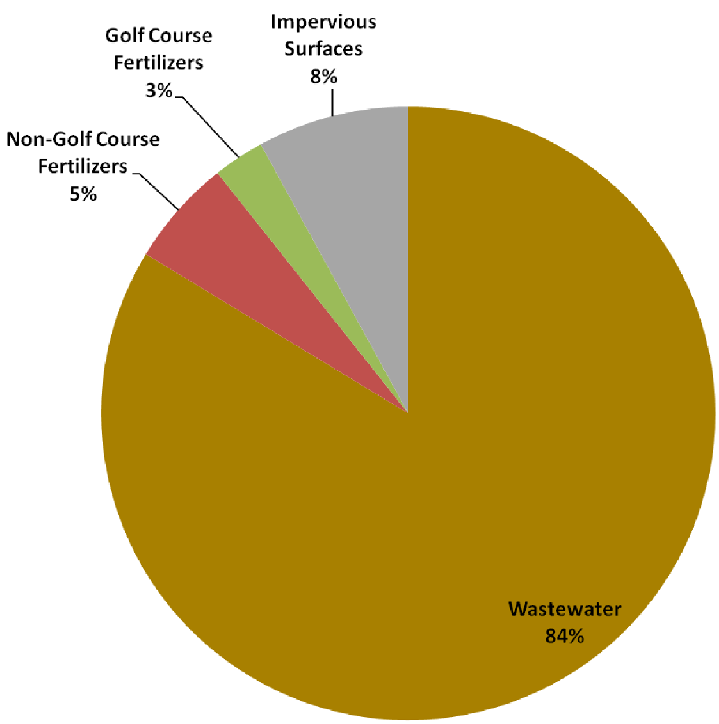


Figure ES-B: Percent Contributions of Controllable Watershed Nitrogen Sources to the Quissett Harbor System



Target Threshold Nitrogen Concentrations and Loadings

The attenuated N loadings (the quantity of nitrogen) to the Quissett Harbor subembayments range from 1.46 kg/day in main or outer Quissett Harbor, to 1.92 kg/day in the upper or inner Quissett Harbor. This represents the total watershed load of natural background, fertilizer, land use runoff, and septic system loading. The observed TN concentrations of N in the subembayments range from 0.30 mg/L (milligrams of nitrogen per liter) in the main Quissett Harbor to 0.35 mg/L in the upper Quissett Harbor (Howes *et. al* 2012, pg. 69) .

In order to restore and protect the Quissett Harbor subembayments, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below the thresholds that cause the observed environmental impacts. This concentration will be referred to as the *target threshold concentration*. It is the goal of the TMDL to reach this target threshold concentration, as it has been determined for each sub-embayment. The Massachusetts Estuaries Project (MEP) has determined that for the Quissett Harbor sub-embayments, a target threshold N concentration of 0.34 mg/L (at sentinel station QH-2) is protective of water quality standards. The mechanism for achieving the target threshold N concentration is to reduce the N loadings to the subembayments.

Based on the MEP work and their resulting Technical Report the Department has determined that the Total Maximum Daily Loads (TMDL) of TN that will meet the target threshold concentrations range from 2.39 to 5.44 kg/day (note: this number is slightly different from the Technical Report, as negative benthic flux was set to zero in the TMDL). To meet the TMDL this report suggests a -21.6% reduction of the total watershed nitrogen load for the entire system. The purpose of this document is to present the TMDL for the subembayment and to provide guidance to the Town on possible ways to reduce the N loadings to implement the proposed TMDL.

Implementation

The primary goal of implementation will be lowering the concentrations of N by greatly reducing the loadings from on-site subsurface wastewater disposal systems through a variety of centralized or decentralized methods such as sewering and treatment with nitrogen removal technology, advanced treatment of septage, upgrade/repairs of failed on-site systems, and/or installation of N-reducing on-site systems.

These strategies, plus methods of reducing N loadings from stormwater runoff and fertilizers, are explained in detail in the "MEP Embayment Restoration Guidance for Implementation Strategies", that is available on the MassDEP website http://www.mass.gov/eea/agencies/massdep/water/watersheds/coastal-resources-and-estuaries.html. The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an adaptive management approach. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under Clean Water Act Section 208. Finally, growth within the communities of Mashpee, Falmouth, and Sandwich (part of the upper watershed only) which would exacerbate the problems associated with N loadings, should be guided by considerations of water quality-associated impacts.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state (1) to identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL allocation establishes the maximum loadings (of pollutants of concern), from all contributing sources, that a water body may receive and still meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.

2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point sources (discernable, confined, and concrete sources such as pipes) and non-point sources (diffuse sources that carry pollutants to surface waters through runoff or groundwater).

3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.

4. Specification of load allocations, based on the loading capacity determination, for non-point sources and point sources that will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDL will serve as a guide for future implementation activities. The MassDEP will work with the Town of Falmouth to develop specific implementation strategies to reduce N loadings, and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Quissett Harbor System, the pollutant of concern for this TMDL (based on observations of eutrophication and some loss of eelgrass), is the nutrient nitrogen. Nitrogen is the limiting nutrient in coastal and marine waters, which means that as its concentration is increased, so is the amount of plant matter. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton which impair eelgrass beds and imperil the healthy ecology of the affected water bodies.

The TMDLs for total N for the Quissett Harbor System are based primarily on data collected, compiled, and analyzed by University of Massachusetts Dartmouth's School of Marine Science and Technology (SMAST), the Cape Cod Commission, the Buzzards Bay Coalition's Monitoring Program (Baywatchers), the Town of Falmouth and others, as part of the Massachusetts Estuaries Project (MEP). The data was collected over a study period from 1999-2008. This study period will be referred to as the "Present Conditions" in the TMDL since it was the most recent data available at the time of model development. The accompanying MEP

Technical Report for Quissett Harbor can be found at
http://www.mass.gov/eea/agencies/massdep/water/watersheds/the-massachusetts-estuaries-project-and-reports.html.

The MEP Technical Report presents the results of the analyses of the sub-embayments using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model). The analyses were performed to assist the Town with decisions on current and future wastewater planning, wetland restoration, anadromous fish runs, shellfisheries, open-space, and harbor maintenance programs. A critical element of this approach is the assessments of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure that were conducted on the sub-embayments studied. These assessments served as the basis for generating N loading thresholds for use as goals for watershed N management. The TMDLs are based on the site-specific thresholds generated. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision-making process in the Town of Falmouth.

Description of Water Bodies and Priority Ranking

Watershed Characterization

The Quissett Harbor embayment system watershed is located entirely within the town of Falmouth. The MEP team, used the United States Geological Survey (USGS), groundwater model as the basis for delineating the Quissett Harbor embayment system. The watershed area is approximately 0.65 square miles. The delineated contributory watershed includes two subwatersheds, inner Quissett Harbor and main Quissett Harbor (Figure 1, Howes *et. al*, 2012, pg. 22).

The MEP project has assessed landuse in the Quissett Harbor embayment system using Town of Falmouth assessor's data. Landuse was summarized into six categories including residential, commercial, multi-use, golf course, public (including rights of way), and undeveloped. The landuse summary follows Massachusetts Department of Revenue classifications (MassDOR 2009) and the public service category signifies tax exempt properties including land owned by government and private non-profits. The most common landuse categories are residential and undeveloped which compromised 51% and 20% of the overall Quissett Harbor watershed respectively (Howes *et. al* 2012, pg. 27). The MEP project team estimates there will be an addition 69 dwelling units at buildout.

Description of Waterbodies

The Quissett Harbor Embayment System in Falmouth Massachusetts, at the southwestern edge of Cape Cod, faces Buzzards Bay to the west with an average depth of 10.4 feet. Quissett Harbor is a well-protected harbor bounded by the Knob to the north and Gansett Point to the south. In addition Quissett Harbor inlet is partially armored as the northern portion of the inlet, the peninsula running to the Knob, is protected with revetments, which protects this portion of the tidal inlet.

For the MEP analysis, the Quissett Harbor is modeled as one basin with no small tributaries but was evaluated as two subembayments, a northern area, inner Quissett Harbor and a southern area, main Quissett Harbor (Figure 1). This was due to the presence of a small shoal that separates the inner and outer basin of the Harbor. The Harbor is one of the Town of Falmouth's moderately sized marine resources and supports an active boatyard as well as a small yacht club.

The sub-embayments studied constitute important components of the Town's natural and cultural resources The nature of enclosed embayments in populous regions brings two opposing elements to bear: (1) as protected marine shoreline they are popular regions for boating, recreation and land development and (2) as enclosed bodies of water they may not be readily flushed of the pollutants that they receive due to the proximity and density of development near and along their shores. Chapter VI and VII of the MEP Technical Report provide data that show that the water and habitat quality of the Quissett Harbor system is impaired because of elevated nutrients, low dissolved oxygen levels, elevated chlorophyll *a* levels, eelgrass loss and degraded benthic fauna habitat (Table 1).

Priority Ranking

The embayment addressed by this TMDL is determined to be a high priority based on three significant factors: (1) the initiative that the town has taken to assess the conditions of the entire estuarine system; (2) the support of the town to restore and preserve the embayment; and (3) the extent of impairment in the embayment. In particular, Quissett Harbor is at risk of further degradation from increased N loads entering through groundwater and surface water from its increasingly developed watersheds. In both marine and freshwater systems, an excess of nutrients results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources. The general conditions related to the major indicators of habitat impairment, due to excess nutrient loadings, are tabulated in Table 2. Observations are summarized in the Problem Assessment section below, and detailed in Chapter VII, Assessment of Embayment Nutrient Related Ecological Health, of the MEP Technical Report.

Description of Hydrodynamics of the Quissett Harbor Embayment System

Tidal water enters the harbor through one deep partially armored inlet. Tidal flows within Quissett Harbor are unrestricted due to the width and depth of the channels. Fresh water enters the Harbor through direct discharge of groundwater as there are no significant streams flowing into it. The small 311 acre Quissett Harbor watershed is located entirely within the Town of Falmouth (Figure 1).

The MEP project has evaluated the tidal circulation and flushing characteristics of this embayment system using both direct measurements and the RMA-2 model, a well established model for estuaries. Using direct measurement of the tides at one location in the embayment system and one offshore location in Buzzards Bay, Howes *et. al* (2012) determined there was little tidal dampening with a delay of the main tidal constituent (M2) that was less than the time step of the tidal data recorders (<10 minutes). The MEP project also determined a system residence time of 1.9 days for this system.

Problem Assessment

Coastal watersheds have seen large increases in population throughout the country. Nutrient loading to coastal embayments has been associated with increases in population. Due to increased population and nutrient loadings many embayments are showing the symptoms of coastal eutrophication which may include reductions in eelgrass biomass, a shift towards a phytoplankton dominated algal community, increased ecosystem metabolism, shifts in benthic infauna, changes in dissolved oxygen dynamics as well as other unhealthy conditions for aquatic life. The loss of eelgrass is of particular concern in coastal embayments since eelgrass habitat serves as a nursery for many fish.

Coastal communities, including Falmouth, rely on clean, productive and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing and boating, as well as commercial fin fishing and shell fishing. The continued degradation of this coastal embayment, will significantly reduce the recreational and commercial value and use of these important environmental resources.

Figure 1: Overview of the Quissett Harbor Embayment System in Falmouth, MA

Table 1: Quissett Harbor MEP Waterbodies with MA 2014 Integrated List and SMAST Impaired Parameters (MassDEP 2015)

Subembayment Name	Water Body Segment	MassDEP Waterbody Description	Size (sq. miles)	Class	303d Category	SMAST Impaired Parameter
Quissett Harbor (**inner**)	MA95-25	The semi-enclosed body of water landward of a line drawn between The Knob and Gansett Point, Falmouth.	0.171	SA (SFO)	4a (Fecal Coliform, EPA TMDL ID 36172)	dissolved oxygen, Chlorophyll, benthic infauna
Quissett Harbor (**main**)						eelgrass

SFO – Shellfishing Open

The watersheds of Quissett Harbor embayment have all had rapid and extensive development of single-family homes and the conversion of seasonal into full time residences. This is reflected in a substantial transformation of land from forest to suburban use between the years 1951 to 2000 (Figure 2). Water quality problems associated with this development result primarily from on-site wastewater treatment systems, and to a lesser extent, from runoff, including fertilizers, from these developed areas.

On-site subsurface wastewater disposal system effluents discharge to the ground, enter the groundwater system and eventually enter the surface water bodies. In the sandy soils of Cape Cod, effluent that has entered the groundwater travel towards the coastal waters at an average rate of one foot per day. The nutrient load to the groundwater system is directly related to the number of subsurface wastewater disposal systems, which in turn are related to the population. The population of Falmouth, as with all of Cape Cod, has increased markedly since 1950. The summer population on Cape Cod is estimated to be two to three times the year round residential population (Howes *et. al*, 2010). The increase in year round residents is illustrated in the following Figure 3 which is based on U.S. Census Bureau data.

The inner Quissett Harbor shows moderate impairment due to slightly elevated chlorophyll levels, periodic dissolved oxygen depletion and a benthic infauna with some organic matter tolerant species especially the deep region (Table 2). This region has enriched sediment with few individuals and those present are organic enrichment tolerant species. Dissolved oxygen was found to be between 3 mg/L and 4mg/L for 22% of the dissolved oxygen probe deployment time.

The nitrogen loading to the Quissett Harbor estuary, like almost all embayments in southeastern Massachusetts, is primarily from on-site disposal of residential (and some commercial) wastewater. The Town of Falmouth, like most of Cape Cod, has seen rapid growth over the past five decades and has minimal (4%) centralized wastewater treatment system or decentralized facilities that remove nitrogen. As such, none of the developed areas in the Quissett Harbor watershed are connected to any municipal sewerage system and wastewater treatment and disposal is primarily through privately maintained on-site septic systems. As present and future increased levels of nutrients impact the coastal embayments in the Town of Falmouth, water quality degradation will increase, with additional impairment and loss of environmental resources, as evidenced by the signs of nutrient enrichment within Quissett Harbor.

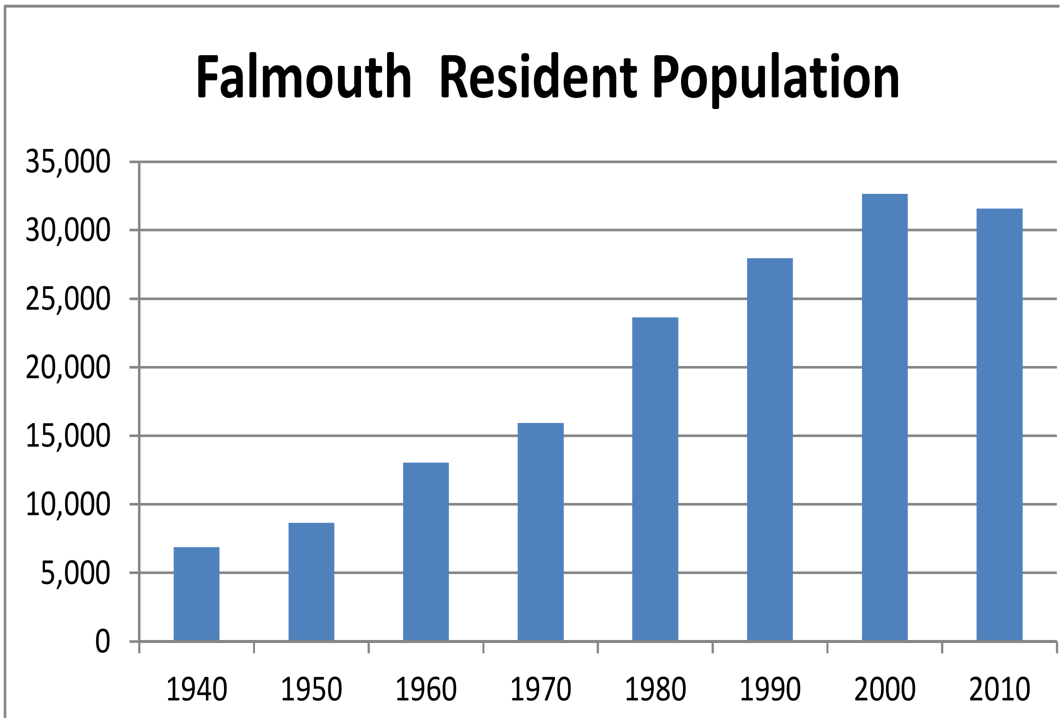

Figure 2: Falmouth Resident Population

The main Quissett Harbor is healthy for the chlorophyll, macroalgae and benthic infauna habitat parameters. The main Quissett Harbor is considered healthy/moderately impaired for dissolved oxygen and eelgrass. There is slight dissolved oxygen depletion (<6mg/L) but dissolved oxygen was found during the MEP project to be greater than 5mg/L for 93% of the dissolved oxygen probe deployment time. Eelgrass in the main harbor is present but there has been loss of eelgrass in the fringing beds between the two portions of the harbor. Quissett Harbor has experienced a 30% loss of eelgrass between 1995 and 2006 as recorded by MassDEP eelgrass mapping efforts. The MEP project has concluded that the “temporal and spatial pattern of this loss from the inner margin of the beds is typical of nitrogen enrichment effects” (Howes *et. al* 2012, pg 98).

Table 2: Quissett Harbor Embayment System MEP Nutrient Related Habitat Quality Determination (extracted from Table VIII-1, Howes *et. al* 2012)

Subembayment	Eelgrass Loss	Dissolved Oxygen Depletion	Chlorophyll *a*[1]	Benthic Fauna[2]	Macroalgae
Quissett Harbor (**inner**)	evidence of eelgrass “presence” in this basin, but density unclear. [**NA**]	deep water mooring oxygen always > 3mg/L , 3-4 mg/L 22% of time, WQMP: <6 mg/L 23% of samples, 2% of samples <4 mg/L, none <3mg/L. [**MI**]	levels low to moderate for a coastal basin, mooring average 10.6 ug /L, but “bloom” event 10-15 ug/L; WQMP 23% of samples >5 ug/L , long-term average 4 ug/L [**H-MI**]	Crustaceans, mollusks, deep burrowers, with organic enrichment tolerant species; mod to high diversity and Evenness, # of species and individuals. Deep region has organic enriched sediments and low #s of individuals from enrichment tolerant species consistent with the sediments and periodic D.O. depletion to <4 mg/L. [**H-MI**]	drift algae generally absent, some small patches [**H**]
Overall Health	The moderate levels of phytoplankton biomass, coupled with periodic D.O. depletion (3-4 mg/L) in the deep basin, results in impaired benthic animal habitat, coupled with the recent loss of eelgrass habitat at the boundary between the Inner and Outer basins all indicate moderate impairment from nitrogen enrichment. Increasing nitrogen loading will cause impairments to the high quality benthic animal habitats bordering the deep portion of this basin. [**MI**]				
Quissett Harbor (**main**)	Supports high quality eelgrass habitat, loss of some fringing beds between the Outer/Inner basins. Temporal and spatial pattern of loss from the inner margin of the beds is typical of N enrichment effects. [**H-MI**]	deep water mooring oxygen always >4 mg/L, >5 mg/L 93% of time, WQMP: always >5 mg/L and >6 mg/L 90% of time [**H-MI**]	levels low for a coastal basin, averaging 6.5 ug L-1, <10 ug/L 88% of record; WQMP: 94% of samples <5 ug/L, long-term average 3 ug/L [**H**]	high numbers of individuals, species (25), diversity (>3) and Evenness (>0.7), community dominated by non-stress indicator species with crustaceans and mollusks, some deep burrowers. [**H**]	drift algae generally absent, some small patches [**H**]
Overall Health	Stable high quality eelgrass habitat from 1951 to present with only recent loss at the margin to the Inner basin; benthic infaunal animal communities are among the most diverse and productive on Cape Cod, with the exception of the deep Cove basin. Loss of marginal eelgrass coverage is indicative of a nitrogen enrichment and rates a designation of “Moderate Impairment” coupled with a “High Quality” habitat designation based upon the general eelgrass and benthic habitat indicators, low chlorophyll and generally high D.O. [**H-MI**]				

*NA= not applicable to this estuarine reach, H= healthy, MI = moderate impairment,
SI= significant impairment, SD= severe degradation
*These terms are more fully described in Howes et. al 2003.
WQMP=Water Quality Monitoring Program

Pollutant of Concern, Sources, and Controllability

In the coastal embayments of the Town of Falmouth, as in most marine and coastal waters, the limiting nutrient is nitrogen. Nitrogen concentrations beyond those expected naturally contribute to undesirable conditions, including the severe impacts described above, through the promotion of excessive growth of plants and algae, including nuisance vegetation.

The embayment covered in this TMDL has had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the Town of Falmouth, the USGS, and the Cape Cod Commission. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report (Howes *et. al* 2012). These investigations revealed that loadings of nutrients, especially N, are much larger than they would be under natural conditions, and as a result the water quality has deteriorated. A principal indicator of decline in water quality is the decline in eelgrass beds within this embayment. This is a result of nutrient loads causing excessive growth of algae in the water (phytoplankton) and algae growing on eelgrass (epiphyton), both of which result in the loss of eelgrass through the reduction of available light levels.

Most of the watershed loading of nitrogen to Quissett Harbor is from on-site subsurface wastewater disposal systems (septic systems, 58%) and atmospheric deposition (28%), with considerably less N originating from fertilizers, impervious surface and natural surfaces (Figure 3a). The nitrogen loading that is considered controllable affecting this system originates predominately from on-site subsurface wastewater disposal systems (septic systems, 84%), impervious surfaces (8%) and fertilizers (both non-golf course and golf course, 8%) (Figure 3b). The level of "controllability" of each nitrogen source, however, varies widely (Table 3). Cost/benefit analyses will have to be conducted on all possible N loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

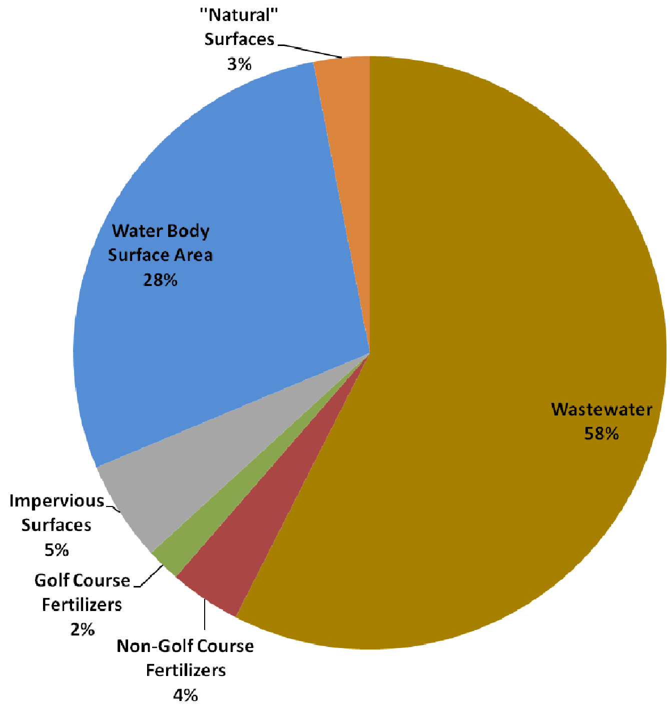

Figure 3a: Percent Contributions of All Watershed Nitrogen Sources to the Quissett Harbor System

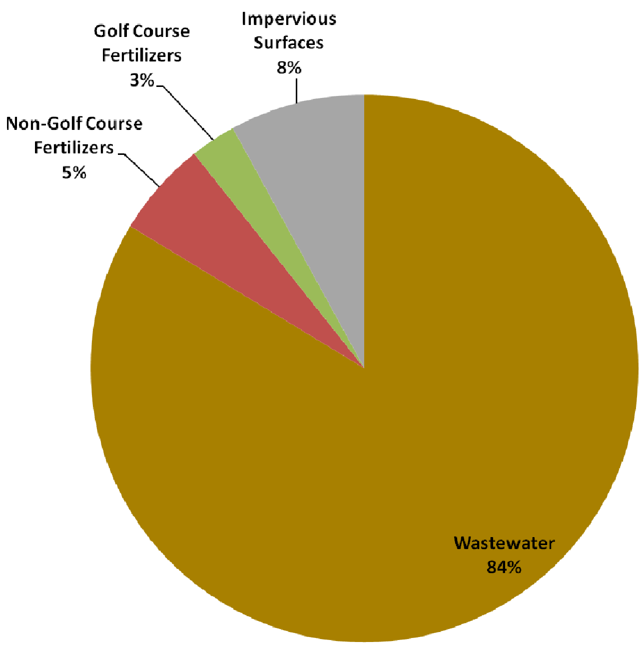

Figure 3b: Percent Contributions of Controllable Watershed Nitrogen Sources to the Quissett Harbor System

Table 3: Sources of Nitrogen and their Controllability

Nitrogen Source	Degree of Controllability at Local Level	Reasoning
Agricultural fertilizer and animal wastes	Moderate	These nitrogen loadings can be controlled through appropriate agricultural Best Management Practices (BMPs).
Atmospheric deposition to the estuary surface	Low	It is only through region- and nation-wide air pollution control initiatives that significant reductions are feasible. Local control although helpful is not adequate.
Atmospheric deposition to natural surfaces (forests, fields, freshwater bodies) in the watershed	Low	Atmospheric deposition (loadings) to these areas cannot adequately be controlled locally. However, the N from these sources might be subjected to enhanced natural attenuation as it moves toward the estuary.
Fertilizer	Moderate	Lawn and golf course fertilizer and related N loadings can be reduced through BMPs, bylaws and public education.
Septic system	High	Sources of N can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, transporting and treating septage at treatment facilities with N removal technology either in or out of the watershed, or installing N-reducing on-site wastewater treatment systems.
Sediment	Low	N loadings are not feasibly controlled on a large scale by such measures as dredging. However, the concentrations of N in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document. In addition, increased dissolved oxygen will help keep N from fluxing.
Stormwater runoff from impervious surfaces	Moderate	This nitrogen source can be controlled by BMPs, bylaws and stormwater infrastructure improvements and public education. Stormwater NPDES permit requirements help control stormwater related N loadings in designated communities.
Wastewater treatment facility (WWTF)	High	Wastewater treatment facilities as point sources of pollution are permitted under the National Pollution Discharge Elimination System. Treated wastewater effluent discharged to groundwater disposal systems are permitted by MassDEP. There is a high degree of regulatory certainty that within the limits of technology, nutrient sources at these facilities can be controlled.

Description of the Applicable Water Quality Standards

The water quality classification of the two portions of the Quissett Harbor that were analyzed as part of the MEP project are SA . Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, aesthetics, and excess plant biomass and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen but have only narrative standards that relate to the other variables. The narrative standards for nutrients (nitrogen and phosphorus) for waters of the Commonwealth are such that "all surface waters shall be free of nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed site specific criteria developed in a TMDL or otherwise, established by the department" (MassDEP 2007). A more thorough explanation of applicable standards can be found in Appendix A.

Thus, the assessment of eutrophication is based on site-specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the US Environmental Protection Agency in their Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (EPA-2001). The guidance manual notes that lakes, reservoirs, streams, and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management. However, individual estuarine and coastal marine waters tend to have unique characteristics, and development of individual water body criteria is typically required.

Methodology – Linking Water Quality and Pollutant Sources

Extensive data collection and analyses have been described in detail in the MEP Technical Report. Those data were used by SMAST to assess the loading capacity of each embayment. Physical (Chapter V), chemical and biological (Chapters IV, VII, and VIII) data were collected and evaluated. The primary water quality objective was represented by conditions that:

1) Restore the natural distribution of eelgrass because it provides valuable habitat for shellfish and finfish;
2) Prevent algal blooms;
3) Restore and preserve benthic communities;
4) Maintain dissolved oxygen concentrations that are protective of the estuarine communities.

The details of the data collection, modeling and evaluation are presented and discussed in Chapters IV, V, VI, VII and VIII of the MEP Technical Report. The main aspects of the data evaluation and modeling approach are summarized below.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and N characteristics, and is characterized as follows:

- Requires site specific measurements within the watershed and each sub-embayment;
- Uses realistic "best-estimates" of N loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- Spatially distributes the watershed N loading to the embayment;

- Accounts for N attenuation during transport to the embayment;
- Includes a 2D or 3D embayment circulation model depending on embayment structure;
- Accounts for basin structure, tidal variations, and dispersion within the embayment;
- Includes N regenerated within the embayment;
- Is validated by both independent hydrodynamic, N concentration, and ecological data;
- Is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model has been applied previously to watershed N management in over 60 embayments thus far throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated and has use as a management tool for evaluating watershed N management options.

The Linked Model, when properly calibrated and validated for a given embayment becomes a N management-planning tool as described in the model overview below. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. Also, since the Linked Model uses a holistic approach that incorporates the entire watershed, embayment and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries. It should be noted that this approach includes high-order, watershed and sub-watershed scale modeling necessary to develop critical nitrogen targets for each major sub-embayment. The models, data and assumptions used in this process are specifically intended for the purposes stated in the MEP Technical Report, upon which this TMDL is based. As such, the Linked Model process does not contain the type of data or level and scale of analysis necessary to predict the fate and transport of nitrogen through groundwater from specific sources. In addition, any determinations related to direct and immediate hydrologic connection to surface waters are beyond the scope of the MEP's Linked Model process.

The Linked Model provides a quantitative approach for determining an embayment's (1) N sensitivity, (2) N threshold loading levels (TMDL) and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation and recycling and variations in tidal hydrodynamics (Figure I-4 of the MEP Technical Report). This methodology integrates a variety of field data and models, specifically:

- Monitoring – multi-year embayment nutrient sampling

- Hydrodynamics –
  - Embayment bathymetry (depth contours throughout the embayment)
  - Site-specific tidal record (timing and height of tides)
  - Water velocity records (in complex systems only)
  - Hydrodynamic model

• Watershed Nitrogen Loading
  - Watershed delineation
  - Stream flow (Q) and N load
  - Land-use analysis (GIS)
  - Watershed N model

• Embayment TMDL – Synthesis
  - Linked Watershed-Embayment Nitrogen Model
  - Salinity surveys (for linked model validation)
  - Rate of N recycling within embayment
  - Dissolved oxygen record
  - Macrophyte survey
  - Infaunal survey (in complex systems)

Application of the Linked Watershed-Embayment Model

The approach developed by the MEP for applying the linked model to specific sub-embayments, for the purpose of developing target N loading rates, includes:

1) selecting one or two sub-embayments within the embayment system, located close to the inland-most reach or reaches, which typically has the poorest water quality within the system. These are called "sentinel" sub-embayments;

2) using site-specific information and a minimum of 3 years of sub-embayment-specific data to select target/threshold N concentrations for each sub-embayment. This is done by refining the draft threshold N concentrations that were developed as the initial step of the MEP process. The target concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

3) running the calibrated water quality model using different watershed N loading rates, to determine the loading rate which will achieve the target N concentration within the sentinel sub-embayment. Differences between the modeled N load required to achieve the target N concentration, and the present watershed N load, represent N management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses and the modeling activities described above resulted in four major outputs that were critical to the development of the TMDL. Two outputs are related to N **concentration**:

- the present N concentrations in the sub-embayments
- site-specific target threshold N concentration

And, two outputs are related to N **loadings:**

- the present attenuated N loads to the sub-embayments

- load reductions necessary to meet the site specific target threshold N concentrations

In summary: if the water quality standards are met by reducing the N concentration (and thus the N load) at the sentinel station, then the water quality goals will be met throughout the entire system. A brief overview of each of the outputs follows:

Nitrogen concentrations in the sub-embayments

1. Observed "present" conditions:

Table 4 presents the average concentrations of N measured in the modeled sub-embayments from 1993 through 2009. The average of the yearly mean nitrogen concentrations in inner basin of Quissett Harbor at station QH2 is 0.354 mg/L (Table 4, Figure 4). The average of the yearly mean nitrogen concentrations in the main Quissett Harbor at station QH1 is 0.302 mg/L. A comparison of the average of yearly mean nitrogen concentrations, standard deviations of the mean yearly nitrogen concentrations and modeled nitrogen concentrations are presented in Appendix B.

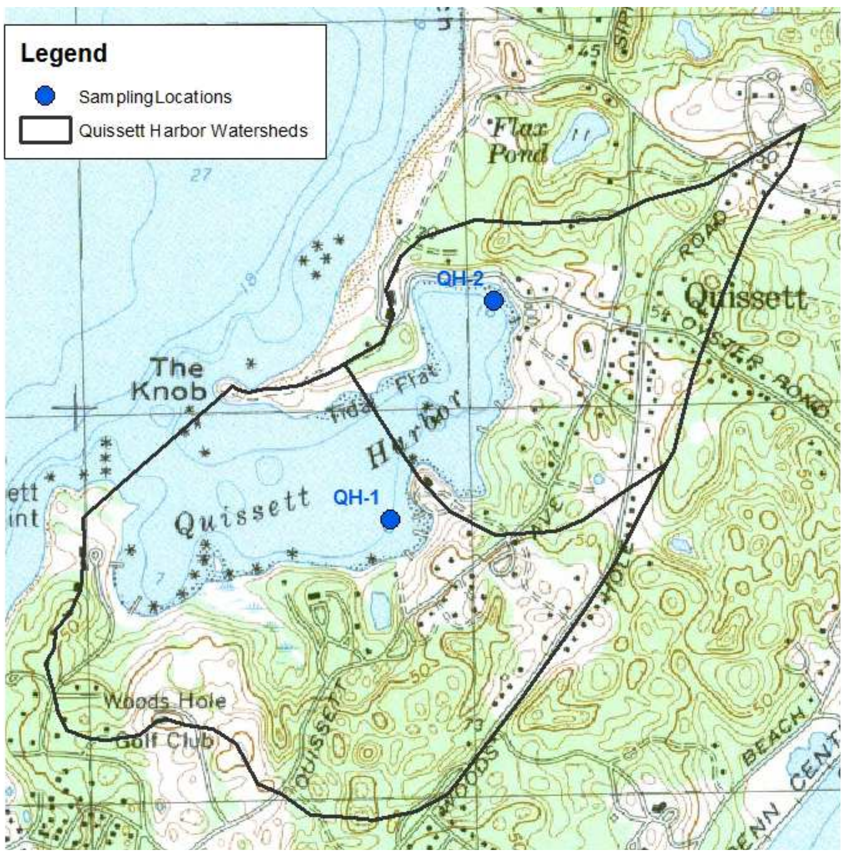

Figure 4: MEP Water Quality Sampling Stations in Quissett Harbor Embayment System

Table 4: Measured nitrogen concentrations for the Quissett Harbor embayment system (excerpted from Howes *et. al*, 2012). Data collected between1993 through 2009.

Sub-Embayment	Station	Mean[1] (mg/L N)	Standard Deviation	Number Samples	**Target[2] Threshold N Concentration** (mg/L)
Quissett Harbor (inner)	QH2	0.354	0.069	66	**0.34**
Quissett Harbor (main)	QH1	0.302	0.055	61	

[1] Mean values are calculated as the average of the separate yearly means.

[2] Sentinel station threshold for eelgrass restoration in the Quissett Harbor inner basin.

2. Modeled site-specific target threshold N concentration

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. Prior to conducting the analytical and modeling activities described above, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and N concentrations. The Linked Model was then used to determine site-specific threshold N concentrations by using the specific physical, chemical and biological characteristics of each subembayments.

Threshold N levels for each of the sub-embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. In this system, the restoration of eelgrass is the main target of overall system restoration. Benthic fauna, dissolved oxygen and chlorophyll *a* were also considered in the assessment. The MEP team has found that "the level of eelgrass impairment it appears that the system is presently only slightly beyond its nitrogen threshold for sustainable eelgrass coverage" (Howes *et. al*, 2012, pg. 101). Nitrogen levels of 0.354 mg/L were associated with no eelgrass coverage in inner Quissett Harbor and loss of sparse eelgrass coverage along its western margin. Generally high quality eelgrass habitat is found at nitrogen levels of 0.302 mg/L in the main Quissett Harbor but with loss of eelgrass in the fringing beds especially near the boundary of the two portions of the harbor.

The sentinel station was based on a comparison to similar local basins with eelgrass that have seen recent eelgrass loss such as Nantucket Harbor Estuary and West Falmouth Harbor. Nantucket Harbor Estuary has seen eelgrass loss at tidally average nitrogen concentrations of 0.340-0.353 in the lower reaches of the Head of the Harbor. Eelgrass loss in West Falmouth Harbor has been associated with tidally averaged total nitrogen concentrations that exceed 0.35 mg/L. It is believed that meeting the target threshold nitrogen concentration within the inner Quissett Harbor will restore eelgrass habitat throughout the system.

Given the current nitrogen concentrations in the embayment and comparison with similar embayments, the threshold N concentration at station QH2, the sentinel station, is 0.34 mg/l (Table 4). Reaching this target threshold N concentration at the sentinel station (QH2) should also result in restoration of benthic fauna habitat.

Present Attenuated Nitrogen Loadings to the Embayment

In the Quissett Harbor System overall, the highest N loading from **controllable** sources is from on-site wastewater treatment systems (84%). The current septic system load is 2.7 kg/day and the total watershed load is approximately 3.4 kg/day (Table 5). Atmospheric deposition and sediments make up 24% and 16% of the total load, respectively, but are not considered controllable. Nitrogen loading from the nutrient-rich sediments (referred to as benthic flux) can be significant in estuarine systems. However, the magnitude of the benthic contribution is related to the watershed load. Therefore, reducing the incoming watershed load should reduce the benthic flux over time. A breakdown of attenuated N loading, by source, is presented in Table 5. This table is based on data from Table ES 1 of the MEP technical report for this embayment system (Howes et. al, 2012).

Nitrogen load reductions necessary for meeting the site-specific target threshold N concentration

The target nitrogen threshold concentration developed by SMAST and summarized above was used in the linked model to determine the amount of total nitrogen mass loading reduction required for restoration of eelgrass and infaunal habitats in the Quissett Harbor Embayment System. Tidally averaged total nitrogen concentrations were used to calibrate the water quality model. Modeled watershed nitrogen loads were sequentially lowered using reductions in septic effluent discharges only until the nitrogen levels reached the threshold level at the sentinel station chosen for the Quissett Harbor Embayment System (Figure 4). It is important to note that load reductions can be produced by reduction of any or all sources of N and/or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment. (Note: there are no significant sources of fresh surface water entering the harbor.)

The load reductions necessary to achieve the target threshold nitrogen concentration at the primary sentinel station are presented in Table 6. The MEP project estimated that a total watershed load reduction of 38% would be needed in the inner Quissett Harbor watershed to meet the target threshold N concentration. These values represent only one of a suite of potential reduction approaches that need to be evaluated by the Town of Falmouth. The presentation is to establish the general degree and spatial pattern of reduction that will be required for restoration of this N impaired embayment. Other alternatives may also achieve the desired target threshold N concentration as well and can be explored using the MEP modeling approach. The Town of Falmouth should take any reasonable actions to reduce the controllable N sources.

Table 5: Present Attenuated Nitrogen Loading to the Quissett Harbor Embayment System (excerpted from Howes et. al, 2012)

Sub-embayment	Present Land Use Load[1] (kg/day)	Present Septic System Load[2] (kg/day)	Present Total Watershed Load[3] (kg/day)	Direct Atmospheric Deposition[4] (kg/day)	Present Net Benthic Flux (kg/day)	Total Load[5] (kg/day)
Quissett Harbor (**inner**)	0.34	1.58	1.92	0.41	4.06	6.39
Quissett Harbor (**main**)	0.34	1.12	1.46	0.93	-3.16	-0.77
System Total	0.68	2.70	3.38	1.33	0.90	5.62

1- composed of non-wastewater loads, e.g. fertilizer and runoff and natural surfaces and atmospheric deposition to lakes

2- septic systems only, no wastewater treatment facility discharges to groundwater within this watershed

3 –composed of combined natural background, fertilizer, runoff, and septic system loadings

4- atmospheric deposition to embayment surface only, not controllable

5-composed of natural background, fertilizer, runoff, septic system atmospheric deposition and benthic flux loadings

Table 6: Present Attenuated Watershed Nitrogen Loading Rates, Calculated Loading Rates that are Necessary to Achieve Target Threshold Nitrogen Concentrations, and the Percent Reductions of the Existing Loads Necessary to Achieve the Target Threshold Loadings System (excerpted from Howes *et. al*, 2012)

Sub-embayment	Present Attenuated Watershed Load[1] (kg/day)	Target Threshold Watershed Load[2] (kg/day)	Percent watershed reductions needed to achieve target threshold loads
Quissett Harbor (**inner**)	1.92	1.19	-38.0%
Quissett Harbor (**main**)	1.46	1.46	0.0%
System Total	3.38	2.65	-21.6%

1- Composed of wastewater from septic systems, fertilizer, runoff from impervious surfaces and atmospheric deposition to freshwater waterbodies. This load does not include direct atmospheric deposition onto estuarine surfaces or benthic regeneration.

2 Target threshold watershed load is the load from the watershed needed to meet the embayment target threshold N concentration. Includes natural background.

Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a water body for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. The TMDLs are established to protect and/or restore the estuarine ecosystem, including eelgrass, the leading indicator of ecological health, thus meeting water quality goals for aquatic life support. Because there are no "numerical" water quality standards for N, the TMDLs for the Quissett Harbor estuarine system are aimed at establishing the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems.

The development of a TMDL requires detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time) for each waterbody system. The results of the mathematical model are correlated with estimates of impacts on water quality, including negative impacts on eelgrass (the primary indicator), as well as dissolved oxygen, chlorophyll *a* and benthic infauna.

The TMDL can be defined by the equation:

$$TMDL = BG + WLAs + Las + MOS$$

Where:
TMDL = Total Maximum Daily Load is the loading capacity of receiving water
BG = natural background
WLAs = Waste Load allocation is the portion allotted to point sources
Las = Load Allocation is the portion allotted to (cultural) non-point sources
MOS = margin of safety

Background Loading

Natural background N loading is included in the loading estimates, but is not quantified or presented separately. Background loading was calculated on the assumption that the entire watershed is forested with no anthropogenic sources of N. It is accounted for in this TMDL but not defined as a separate component. Readers are referred to Table ES-1 of the MEP Technical Report for estimated loading due to natural conditions (Howes *et. al*, 2012).

Wasteload Allocations

Waste load allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. In the Quissett Harbor embayment system there are no permitted surface water discharges in the watershed with the exception of stormwater. A TMDL may establish a specific WLA for an identified source or, as in the case of stormwater, may establish an aggregate WLA that applies to numerous sources. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of stormwater be included in the waste load component of the TMDL.

For purposes of the Quissett Harbor embayment system TMDLs, MassDEP also considered the nitrogen load reductions from regulated MS4 sources necessary to meet the target nitrogen concentrations. In estimating the nitrogen loadings from regulated stormwater sources, MassDEP considered that most stormwater runoff in the MS4 communities is not discharged directly into surface waters, but, rather, percolates into the ground. The geology on Cape Cod and the Islands consists primarily of glacial outwash sands and gravels, and water moves rapidly through this type of soil profile. A systematic survey of stormwater conveyances on Cape Cod and the Islands was never undertaken prior to the MEP study used in the development of this TMDL. Nevertheless, most catch basins on Cape Cod and the Islands are known to MassDEP to have been designed as leaching catch basins in light of the permeable overburden. MassDEP, therefore, recognized that most stormwater that enters a catch basin in the regulated area will percolate into the local groundwater table rather than directly discharge to a surface waterbody.

As described in the Methodology Section (above), the Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source. However, MassDEP also considered that some stormwater collected in the regulated area is discharged directly to surface waters through outfalls.

In the absence of specific data or other information to accurately quantify stormwater discharged directly to surface waters, MassDEP assumed that all impervious surfaces within 200 feet of the shoreline, as calculated from MassGIS data layers, would discharge directly to surface waters, whether or not it in fact did so. MassDEP selected this approach because it considered it unlikely that any stormwater collected farther than 200 ft. from the shoreline would be directly discharged into surface waters.

Although the 200 foot approach provided a gross estimate, MassDEP considered it a reasonable and conservative approach given the lack of pertinent data and information about MS4 systems on Cape Cod. The calculated stormwater WLA based on the 200 foot buffer is calculated load for the whole embayment system is 0.03 kg/day is less than 1% of the total unattenuated watershed N load of 3.38 kg/day to the embayment (see Appendix C for details). This conservative load is negligible when compared to other sources.

Load Allocations

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Quissett Harbor System sub-embayments studied, the nonpoint source loadings are primarily from on-site subsurface wastewater disposal systems. Additional N sources include: natural background, stormwater runoff (except from impervious cover within 200 feet of the waterbody which is defined above as part of the waste load as discussed above), N from fertilizers, and atmospheric deposition (to both freshwater and estuarine waterbodies and natural surfaces), and nutrient-rich sediments. These sources together are all considered part of the watershed load of nitrogen. Watershed sources of controllable attenuated nitrogen were detailed above in Table 5 and also Figure 1.

Generally, stormwater that is subject to the EPA Phase II Program would be considered a part of the wasteload allocation, rather than the load allocation. As presented in Chapter IV, V, and VI, of the MEP Technical Report, on Cape Cod the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater. Given this, the TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and stormwater for the purpose of developing control strategies. Continued Phase II Program implementation in Falmouth, new studies, and possibly further modeling, will identify what portion of the stormwater load may be controllable through the application of Best Management Practices (BMPs).

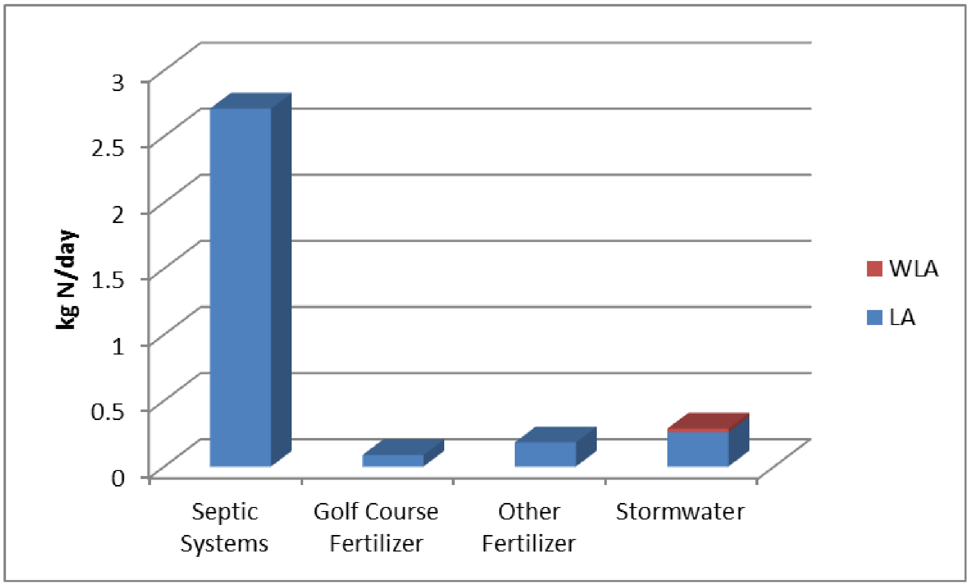

Figure 5: Quissett Harbor System Locally Controllable N Loads by Source

The sediment loading rates incorporated into the TMDL are lower than the existing sediment flux rates in Table 5 above, because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments, and therefore, over time, reductions in loadings from the sediments will occur. Benthic flux of nitrogen from bottom sediments is a critical (but often overlooked) component of nitrogen loading to the shallow estuarine systems, therefore determination of the site specific magnitude of this component was also performed (see Section VI of the the MEP Report).

Benthic N flux is a function of N loading and particulate organic nitrogen (PON). Projected benthic fluxes are based upon projected PON concentrations and watershed N loads, and are calculated by multiplying the present N flux by the ratio of projected PON to present PON, using the following formulae:

Projected N flux = (present N flux) (PON projected / PON present)

When: PON projected = $(R_{load})(D_{PON}) + PON_{present\ offshore}$

When: R_{load} = (projected N load) / (Present N load)

And: D_{PON} is the PON concentration above background determined by:

$$D_{PON} = (PON_{present\ embayment} - PON_{present\ offshore})$$

Typically, the sediment loading rates incorporated into the TMDL are lower than the existing sediment flux rates listed in Table 5 above because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments, and therefore, over time, reductions in loadings from the sediments will occur.

For Quissett Harbor, the MEP study reported negative benthic flux load (Table 5, above). Negative benthic flux was incorporated into the water quality model to determine the watershed N load and the necessary watershed load reductions, however MassDEP has determined that negative loads are not appropriate for incorporating into the TMDL. The TMDL by definition is for regulation of loading inputs and, as such, a negative number for a load does not apply. Accordingly, negative benthic flux loads were set to zero for determination of the TMDL.

The loadings from atmospheric sources incorporated into the TMDL, however, are the same rates presently occurring, because, as discussed above, local control of atmospheric loadings is not considered feasible.

Locally controllable sources of N within the watersheds are categorized as on-site subsurface wastewater disposal system wastes and land use (which includes stormwater runoff and fertilizers). The overwhelming majority of locally controllable N comes from on-site subsurface wastewater disposal systems (Figure 3b).

Margin of Safety

Statutes and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA para 303 (d)(20©, 40C.G.R. para 130.7©(1)]. The MOS must be designed to ensure that any uncertainties in the data or calculations used to link pollutant sources to water quality impairment modeling will be accounted for in the TMDL and ensure protection of the beneficial uses. The EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. An explicit MOS quantifies an allocation amount separate from other Load and Wasteload Allocations. An explicit MOS can incorporate reserve capacity for future unknowns, such as population growth or effects of climate change on water quality. An implicit MOS is not specifically quantified but consists of statements of the conservative assumptions used in the analysis. The MOS for the Quissett Harbor estuarine system TMDL is implicit. MassDEP used conservative assumptions to develop numeric model applications that account for the MOS. These assumptions are described below, and they account for all sources of uncertainty, including the potential impacts of changes in climate.

While the general vulnerabilities of coastal areas to climate change can be identified, specific impacts and effects of changing estuarine conditions are not well known at this time (http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/climate-change-adaptation/climate-change-adaptation-report.html). Because the science is not yet available, MassDEP is unable to analyze climate change impacts on streamflow, precipitation, and nutrient loading with any degree of certainty for TMDL development. In light of these uncertainties and informational gaps, MassDEP has opted to address all sources of uncertainty through an implicit MOS. MassDEP does not believe that an explicit MOS approach is appropriate under the circumstances or will provide a more protective or accurate MOS than the implicit MOS approach, as the available data simply does not lend itself to characterizing and estimating loadings to derive numeric allocations within confidence limits. Although the implicit MOS approach does not expressly set aside a specific portion of the load to account for potential impacts of climate change, MassDEP has no basis to conclude that the conservative assumptions that were used to develop the numeric model applications are insufficient to account for the lack of knowledge regarding climate change.

Conservative assumptions that support an implicit MOS:

1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayment. Nitrogen transfer through direct groundwater discharge to estuarine waters is based upon studies indicating negligible aquifer attenuation and dilution, i.e. 100% of load enters embayment. This is a conservative estimate of loading because studies have also shown that in some areas less than 100% of the load enters the estuary. In this context, “direct groundwater discharge” refers to the portion of fresh water that enters an estuary as groundwater seepage into the estuary itself, as opposed to the portion of fresh water that enters as surface water inflow from streams. Nitrogen transport through surface water systems, unlike aerobic aquifers supports the conditions for nitrogen retention and denitrification. As there were no significant streams or great fresh ponds within the Quissett Harbor watershed, the watershed loading approach considered that nitrogen reaching the water table was transported without attenuation through the groundwater system until discharge to the estuary.

The hydrodynamic and water quality models have been assessed directly. In the many instances where the hydrodynamic model predictions of volumetric exchange (flushing) have also been directly measured by field measurements of instantaneous discharge, the agreement between modeled and observed values has been >95%. The hydrodynamic modeling showed strong agreement between measured and modeled tides. The error associated with tidal height was less than the accuracy of the tidal gage (+/-0.12 ft). Since the water quality model incorporates all of the outputs from the other models, this excellent fit indicates a high degree of certainty in the final result. The high level of accuracy of the model provides a high degree of confidence in the output; therefore, less of a margin of safety is required.

Similarly, the water column N validation dataset was also conservative. The model is validated to measured water column N. However, the model predicts average summer N concentrations. The very high or low measurements are marked as outliers. The effect is to make the N threshold more accurate and scientifically defensible. If a single measurement two times higher than the next highest data point in the series raises the average 0.05 mg N/L, this would allow for a higher "acceptable" load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the N threshold for a system. This effectively strengthens the data set so that a higher margin of safety is not required.

Finally, the predicted reductions in benthic regeneration of N are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of PON, due to lower primary production rates under the reduced N loading in these systems. As the N loading decreases and organic inputs are reduced, it is likely that rates of coupled remineralization-nitrification, denitrification and sediment oxidation will increase. It was also conservatively assumed that the present benthic flux uptake measured in Quissett Harbor (-3.16 kg/day) does not exist under future loading conditions and as such was designated as "0" for purposes of the TMDL.

Benthic regeneration of N is dependent upon the amount of PON deposited to the sediments and the percentage that is regenerated to the water column versus being denitrified or buried. The regeneration rate projected under reduced N loading conditions was based upon two assumptions (1) PON in the embayment in excess of that of inflowing tidal water (boundary condition) results from production supported by watershed N inputs and (2) Presently enhanced production will decrease in proportion to the reduction in the sum of watershed N inputs and direct atmospheric N input. The latter condition would result in equal embayment versus boundary condition production and PON levels if watershed N loading and direct atmospheric deposition could be reduced to zero (an impossibility of course). This proportional reduction assumes that the proportion of remineralized N will be the same as under present conditions, which is almost certainly an underestimate. As a result, future N regeneration rates are overestimated which adds to the margin of safety.

2. <u>Conservative sentinel station/target threshold nitrogen concentration</u>

Conservatism was used in the selection of the sentinel stations and target threshold N concentrations. The sites were chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher N concentration. Meeting the target threshold N concentrations at the sentinel stations will result in reductions of N concentrations in the rest of the system.

3. <u>Conservative approach</u>

The target loads were based on tidally averaged N concentrations on the outgoing tide, which is the worst case condition because that is when the N concentrations are the highest. The N concentrations will be lower on the flood tides and therefore this approach is conservative.

Finally, the linked model accounted for all stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source and this aggregate load is accounted for in the load allocation. The method of calculating the WLA in the TMDL for regulated stormwater was conservative as it did not disaggregate this negligible load from the modeled stormwater LA; hence this approach further enhances the margin of safety.

In addition to the margin of safety within the context of setting the N threshold levels as described above, a programmatic margin of safety also derives from continued monitoring of these embayments to support adaptive management. This continuous monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the N management plan. This will allow refinements to the plan to ensure that the desired level of restoration is achieved.

Seasonal Variation

Since the TMDL for this embayment system is based on the most critical time period, i.e. the summer growing season, the TMDL is protective for all seasons. Nutrient loads to the embayment as determined during the MEP project are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Second, as a practical matter, the types of controls necessary to control the N load, the nutrient of primary concern, by their very nature do not lend themselves to intra-annual manipulation since the majority of the N is from non-point sources. Thus, the annual loads make sense, since it is difficult to control non-point sources of nitrogen on a seasonal basis and that nitrogen sources can take considerable time to migrate to impacted waters. These annual loads have generally been described as daily loads for the purpose of this TMDL by dividing annual loads by 365 (the number of days in a year).

TMDL Values for Quissett Harbor

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of each sub-embayment were calculated by considering all sources of N grouped by natural background, point sources, and non-point sources. A more meaningful way of presenting the loadings data, from an implementation perspective, is presented in Table 7 and Appendix D. In this table the N loadings from the atmosphere and nutrient-rich sediments are listed separately from the target watershed threshold loads, which are composed of natural background N along with on-site subsurface wastewater disposal systems, stormwater runoff, and fertilizers. In the case of the Quissett Harbor sub-embayments that were studied, the TMDLs were calculated by projecting reductions in locally controllable on-site subsurface wastewater disposal systems, stormwater runoff, and fertilizer sources. Once again the goal of this TMDL is to achieve the identified N threshold concentration in the identified sentinel station. The target load identified in this table represents one alternative loading scenario to achieve that goal but other scenarios may be possible and approvable as well.

Table 7: Total Maximum Daily Loads for the Quissett Harbor Embayment System (excerpted from Howes *et. al*, 2012)

Subembayment	Target Threshold Watershed Load[1] (kg/day)	Atmospheric Deposition (kg/day)	Projected Benthic Load[2] (kg/day)	TMDL[3] (kg/day)	Percent watershed reductions needed to achieve threshold watershed loads
Quissett Harbor (inner)	1.192	0.409	3.84	5.441	-38.0%
Quissett Harbor (main)	1.458	0.928	0	2.386	0.0%
System Total	2.65	1.337	3.84	7.827	-21.6%

1-Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentration identified in Table 6.
2-Projected sediment N loadings obtained by reducing the present loading rates (Table 5) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON. Negative fluxes set to zero.
3-Sum of target threshold watershed load, atmospheric deposition and benthic load.

Implementation

The critical element of this TMDL process is achieving the specific target threshold N concentrations presented in Table 7 above, that are necessary for the restoration and protection of water quality and eelgrass habitat within the Quissett Harbor sub-embayments studied. In order to achieve the target threshold concentration, N loading rates must be reduced throughout the Quissett Harbor System with specific attention to the inner Quissett Harbor watershed. Table 7, above, lists target watershed threshold loads for the two sub-embayments studied. If those threshold loads are achieved, Quissett Harbor will be protected.

Septic Systems:
Table 8 summarizes the present attenuated loadings from septic systems and the necessary reduction in septic loads needed to achieve the target threshold N concentration in the Quissett Harbor embayment system under the scenario modeled here. A 46% reduction in present septic loading to the inner Quissett Harbor achieved the target threshold N concentration of 0.34 mg/L at the sentinel station.

Table 8: Summary of the Present Septic System Loads and the Loading Reductions that would be Necessary to Achieve the TMDL by Reducing Septic System Loads Alone (excerpted from Howes *et. al*, 2012)

Subembayment	Present Septic Load (kg N/day)	Target Septic Load (kg N/day)	Percent Septic Load Reductions Needed to Achieve Target
Quissett Harbor (inner)	1.58	0.86	-46.00%
Quissett Harbor (main)	1.12	1.12	0.00%
System Total	2.7	1.98	-26.70%

As previously noted, this loading reduction scenario is not the only way to achieve the target N concentrations. Local officials are encouraged to explore other loading reduction scenarios through additional modeling as part of their Comprehensive Wastewater Management Plan (CWMP). It must be demonstrated however, that any alternative implementation strategies will be protective of the entire embayment system. To this end, additional linked model runs can be performed by the MEP at a nominal cost to assist the planning efforts of the town in achieving target N loads that will result in the desired target threshold N concentration.

The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the MassDEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under the Clean Water Act Section 208 (aka 208 Plan).

Because the vast majority of controllable N load is from individual on-site subsurface wastewater disposal systems for private residences, the CWMP should assess the most cost-effective options for achieving the target N watershed loads, including but not limited to, sewering and treatment for N control of sewage and septage at either centralized or de-centralized locations, and denitrifying systems for all private residences.

Stormwater:
EPA and MassDEP authorized most of the watershed community of Falmouth for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. EPA and MassDEP reissued the MS4 permit in April 2016. The reissued permit takes effect on July 1, 2017. The NPDES permits which EPA has issued in Massachusetts to implement the Phase II Stormwater program do not establish numeric effluent limitations for stormwater discharges; rather, they establish narrative requirements, including best management practices, to meet the following six minimum control measures and to meet State Water Quality Standards.

1. public education and outreach particularly on the proper disposal of pet waste,
2. public participation/involvement,
3. illicit discharge detection and elimination,
4. construction site runoff control,
5. post construction runoff control, and
6. pollution prevention/good housekeeping.

As part of their applications for Phase II permit coverage, communities must identify the best management practices they will use to comply with each of these six minimum control measures and the measurable goals they have set for each measure. Therefore, compliance with the requirements of the Phase II stormwater permit in the Town of Falmouth will contribute to the goal of reducing the nitrogen load as prescribed in this TMDL for Quissett Harbor watersheds.

In the 2016 annual Phase II MS4 Stormwater report to EPA, Falmouth reported almost 4 miles of Low Impact Development roadway projects currently under design or construction and revising the stormwater by-law and public education programs. In addition, the Town is continuing street sweeping and catch basin cleaning programs, stormdrain stenciling, public service announcements, and monthly meetings held by the engineering department with a focus on coastal ponds and estuaries.

Climate Change:
MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are possible based on known science. Massachusetts Executive Office of Energy and Environmental Affairs 2011 Climate Change Adaptation Report: http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/climate-change-adaptation/climate-change-adaptation-report.html predicts that by 2100 the sea level could be from 1 to 6 feet higher than the current position and precipitation rates in the Northeast could increase by as much as 20 percent. However, the details of how climate change will affect sea level rise, precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. The ongoing debate is not about whether climate change will occur, but the rate at and the extent to which it will occur and the adjustments needed to address its impacts. EPA's 2012 Climate Change Strategy http://water.epa.gov/scitech/climatechange/upload/epa_2012_climate_water_strategy_full_report_final.pdf states: "Despite increasing understanding of climate change, there still remain questions about the scope and timing of climate change impacts, especially at the local scale where most water-related decisions are made." For estuarine TMDLs in southeastern Massachusetts, MassDEP recognizes that this is particularly true, where water quality management decisions and implementation actions are generally made and conducted at the municipal level on a sub-watershed scale.

EPA's Climate Change Strategy identifies the types of research needed to support the goals and strategic actions to respond to climate change. EPA acknowledges that data are missing or not available for making water resource management decisions under changing climate conditions. In addition, EPA recognizes the limitation of current modeling in predicting the pace and magnitude of localized climate change impacts and recommends further exploration of the use of tools, such as atmospheric, precipitation and climate change models, to help states evaluate pollutant load impacts under a range of projected climatic shifts.

In 2013, EPA released a study entitled, "Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds." (National Center for Environmental Assessment, Washington D.C.; EPA/600/R-12/058F). The closest watershed to southeastern Massachusetts that was examined in this study is a New England coastal basin located between Southern Maine and Central Coastal Massachusetts. These watersheds do not encompass any of the watersheds in the Massachusetts Estuary Project (MEP) region, and it has vastly different watershed characteristics, including soils, geography, hydrology and land use – key components used in a modeling analysis. The initial "first order" conclusion of this study is that, in many locations, future conditions, including water quality, are likely to be different from past experience. However, most significantly, this study did not demonstrate that changes to TMDLs (the water quality restoration targets) would be necessary for the region. EPA's 2012 Climate Change Strategy also acknowledges that the Northeast, including New England, needs to develop standardized regional assumptions regarding future climate change impacts. EPA's 2013 modeling study does not provide the scientific methods and robust datasets needed to predict specific long-term climate change impacts in the MEP region to inform TMDL development.

MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind. Adjustments can be made as environmental conditions, pollutant sources, or other factors change over time. Massachusetts Coastal Zone Management (CZM) has developed a StormSmart Coasts Program (2008) to help coastal communities address impacts and effects of erosion, storm surge and flooding which are increasing due to climate change. The program, www.mass.gov/czm/stormsmart offers technical information, planning strategies, legal and regulatory tools to communities to adapt to climate change impacts.

As more information and tools become available, there may be opportunities to make adjustments in TMDLs in the future to address predictable climate change impacts. When the science can support assumptions about the effects of climate change on the nitrogen loadings to the Quissett Harbor embayment system the TMDL can be reopened, if warranted.

MassDEP Guidance:

The Massachusetts Estuaries Project: Embayment Restoration and Guidance for Implementation Strategies (MassDEP 2003) (http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/mepmain.pdf) provides N loading reduction strategies that are available to the Town of Falmouth, and that could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- Wastewater Treatment
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment
    - Community Treatment Plants
    - Municipal Treatment Plants and Sewers
- Tidal Flushing
    - Channel Dredging
    - Inlet Alteration
    - Culvert Design and Improvements
- Stormwater Control and Treatment *
    - Source Control and Pollution Prevention
    - Stormwater Treatment
- Attenuation via Wetlands and Ponds
- Water Conservation and Water Reuse
- Management Districts
- Land Use Planning and Controls
    - Smart Growth
    - Open Space Acquisition
    - Zoning and Related Tools
- Nutrient Trading

* The Town of Falmouth is one of 237 communities in Massachusetts covered by the Phase II stormwater program requirements.

Falmouth is urged to meet the target threshold N concentrations by reducing N loadings from any and all sources, through whatever means are available and practical, including reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater BMPs, in addition to reductions in on-site subsurface wastewater disposal system loadings.

The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an adaptive management approach. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under Clean Water Act Section 208.

Monitoring Plan

MassDEP believes that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. MassDEP's position is that TMDL implementation will be conducted through an iterative process where adjustments maybe needed in the future. The two forms of monitoring include 1) tracking implementation progress as approved in the CWMP plan and 2) monitoring water quality and habitat conditions in the estuaries, including but not limited to, the sentinel stations identified in the MEP Technical Report.

The CWMP will evaluate various options to achieve the goals set out in the TMDL report and the MEP Technical Report. It will also make a final recommendation based on existing or additional modeling runs, set out required activities, and identify a schedule to achieve the most cost effective solution that will result in compliance with the TMDL. Once approved by MassDEP, tracking progress on the agreed upon plan will, in effect, also be tracking progress towards water quality improvements in conformance with the TMDL.

Relative to water quality MassDEP believes that an ambient monitoring program reduced from the data collection activities needed to properly assess conditions and to populate the model, will be important to determine actual compliance with water quality standards. Although the TMDL values are not fixed, the target threshold N concentrations at the sentinel stations are fixed. Through discussions amongst the MEP it is generally agreed that existing monitoring programs which were designed to thoroughly assess conditions and populate water quality models can be substantially reduced for compliance monitoring purposes.

Although more specific details need to be developed on a case-by-case basis MassDEP believes that about half the current effort (using the same data collection procedures) would be sufficient to monitor compliance over time and to observe trends in water quality changes. In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years. Finally, in addition to the above, existing monitoring conducted by MassDEP for eelgrass should continue into the future to observe any changes that may occur to eelgrass populations as a result of restoration efforts.

The MEP will continue working with the Town of Falmouth to develop and refine monitoring plans that remain consistent with the goals of the TMDL. Through the adaptive management approach ongoing monitoring will be conducted and will indicate if water quality standards are being met. If this does not occur other management activities would have to be identified and considered to reach to goals outlined in this TMDL. It must be recognized however that development and implementation of a monitoring plan will take some time, but it is more important at this point to focus efforts on reducing existing watershed loads to achieve water quality goals.

Reasonable Assurances

MassDEP possesses the statutory and regulatory authority, under the water quality standards and/or the State Clean Water Act (CWA), to implement and enforce the provisions of the TMDL through its many permitting programs including requirements for N loading reductions from on-site subsurface wastewater disposal systems. However, because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. The Town of Falmouth has demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The towns expect to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems, agriculture, stormwater runoff (including lawn fertilizers), and to prevent any future degradation of these valuable resources. As the town of Falmouth implements these TMDLs the loading values (kg/day of N) will be used by MassDEP for guidance for permitting activities and should be used by the community as a management tool.

Reasonable assurances that the TMDL will be implemented include enforcement of regulations, availability of financial incentives and local, state and federal programs for pollution control. EPA's Stormwater NPDES permit coverage will address discharges from municipally owned stormwater drainage systems. Enforcement of regulations controlling non-point discharges include local implementation of the Commonwealth's Wetlands Protection Act and Rivers Protection Act, Title 5 regulations for on-site subsurface wastewater disposal systems and other local regulations (such as the Town of Rehoboth's stable regulations).

Financial incentives include federal funds available under Sections 319 and 604 programs of the CWA, which are provided as part of the Performance Partnership Agreement between MassDEP and EPA. Other potential funds and assistance are available through Massachusetts' Department of Agriculture's Enhancement Program and the United States Department of Agriculture's Natural Resources Conservation Services. Additional financial incentives include income tax credits for Title 5 upgrades and low interest loans for Title 5 on-site subsurface wastewater disposal system upgrades available through municipalities participating in this portion of the state revolving fund program.

During TMDL implementation by the Town of Falmouth, the TMDL values (kg/day of N) will be used by MassDEP as guidelines for permitting activities and should be used by the local community as a management tool.

Public Participation
To be completed after the public meeting and comment period has ended.

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Appendix A: Overview of Applicable Water Quality Standards

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, bottom pollutants or alterations, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen, but have only narrative standards that relate to the other variables. This brief summary does not supersede or replace 314 CMR 4.0 Massachusetts Water Quality Standards, the official and legal standards. A complete version of 314 CMR 4.0 Massachusetts Water Quality Standards is available online at http://www.mass.gov/eea/agencies/massdep/water/regulations/314-cmr-4-00-mass-surface-water-quality-standards.html

Applicable Narrative Standards

314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(b) states "Bottom Pollutants or Alterations. All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms."

314 CMR 4.05(5)© states, "Nutrients –Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control."

Description of Coastal and Marine Classes and Numeric Dissolved Oxygen Standards

Excerpt from 314 CMR 4.05(4) (a):

(4) Class SA. These waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be

suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.

4. Dissolved Oxygen. Shall not be less than 6.0 mg/l. Where natural background conditions are lower, DO shall not be less than natural background. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Excerpt from 314 CMR 4.05(4) (b):

(b) Class SB. These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.

4. Dissolved Oxygen. Shall not be less than 5.0 mg/l. Seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. Where natural background conditions are lower, DO shall not be less than natural background.

Waterbodies Not Specifically Designated in 314 CMR 4.06 or the tables to 314 CMR 4.00

Note many waterbodies do not have a specific water quality designation in 314 CMR 4.06 or the tables to 314 CMR 4.00**.** Coastal and Marine Classes of water are designated as Class SA and presumed High Quality Waters as described in 314 CMR 4.06 (4).

314 CMR 4.06(4):

(4) Other Waters. Unless otherwise designated in 314 CMR 4.06 or unless otherwise listed in the tables to 314 CMR 4.00, other waters are Class B, and presumed High Quality Waters for inland waters and Class SA, and presumed High Quality Waters for coastal and marine waters. Inland fisheries designations and coastal and marine shellfishing designations for unlisted waters shall be made on a case-by-case basis as necessary.

Applicable Antidegradation Provisions

Applicable antidegradation provisions are detailed in 314 CMR 4.04 from which an excerpt is provided:

Excerpt from 314 CMR 4.04:
4.04:Antidegradation Provisions

(4) Protection of Existing Uses. In all cases existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

(2) Protection of High Quality Waters. High Quality waters are waters whose quality exceeds minimum levels necessary to support the national goal uses, low flow waters, and

other waters whose character cannot be adequately described or protected by traditional criteria. These waters shall be protected and maintained for their existing level of quality unless limited degradation by a new or increased discharge is authorized by the Department pursuant to 314 CMR 4.04(5). Limited degradation also may be allowed by the Department where it determines that a new or increased discharge is insignificant because it does not have the potential to impair any existing or designated water use and does not have the potential to cause any significant lowering of water quality.

(3) Protection of Outstanding Resource Waters. Certain waters are designated for protection under this provision in 314 CMR 4.06. These waters include Class A Public Water Supplies (314 CMR 4.06(1)(d)1.) and their tributaries, certain wetlands as specified in 314 CMR 4.06(2) and other waters as determined by the Department based on their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these waters shall be protected and maintained.

(a) Any person having an existing discharge to these waters shall cease said discharge and connect to a Publicly Owned Treatment Works (POTW) unless it is shown by said person that such a connection is not reasonably available or feasible. Existing discharges not connected to a POTW shall be provided with the highest and best practical method of waste treatment determined by the Department as necessary to protect and maintain the outstanding resource water.

(b) A new or increased discharge to an Outstanding Resource Water is prohibited unless:

1. the discharge is determined by the Department to be for the express purpose and intent of maintaining or enhancing the resource for its designated use and an authorization is granted as provided in 314 CMR 4.04(5). The Department's determination to allow a new or increased discharge shall be made in agreement with the federal, state, local or private entity recognized by the Department as having direct control of the water resource or governing water use; or

4. the discharge is dredged or fill material for qualifying activities in limited circumstances, after an alternatives analysis which considers the Outstanding Resource Water designation and further minimization of any adverse impacts. Specifically, a discharge of dredged or fill material is allowed only to the limited extent specified in 314 CMR 9.00 and 314 CMR 4.06(1)(d). The Department retains the authority to deny discharges which meet the criteria of 314 CMR 9.00 but will result in substantial adverse impacts to the physical, chemical, or biological integrity of surface waters of the Commonwealth

(4) Protection of Special Resource Waters. Certain waters of exceptional significance, such as waters in national or state parks and wildlife refuges, may be designated by the Department in 314 CMR 4.06 as Special Resource Waters (SRWs). The quality of these waters shall be maintained and protected so that no new or increased discharge and no new or increased discharge to a tributary to a SRW that would result in lower water quality in the SRW may be allowed, except where:

(a) the discharge results in temporary and short term changes in the quality of the SRW, provided that the discharge does not permanently lower water quality or result in water quality lower than necessary to protect uses; and

(b) an authorization is granted pursuant to 314 CMR 4.04(5).

(5) Authorizations.

(a) An authorization to discharge to waters designated for protection under 314 CMR 4.04(2) may be issued by the Department where the applicant demonstrates that:

1. The discharge is necessary to accommodate important economic or social development in the area in which the waters are located;

2. No less environmentally damaging alternative site for the activity, receptor for the disposal, or method of elimination of the discharge is reasonably available or feasible;

3. To the maximum extent feasible, the discharge and activity are designed and conducted to minimize adverse impacts on water quality, including implementation of source reduction practices; and

4. The discharge will not impair existing water uses and will not result in a level of water quality less than that specified for the Class.

(b) An authorization to discharge to the narrow extent allowed in 314 CMR 4.04(3) or 314 CMR 4.04(4) may be granted by the Department where the applicant demonstrates compliance with 314 CMR 4.04(5)(a)2. Through 314 CMR 4.04(5)(a)4.

© Where an authorization is at issue, the Department shall circulate a public notice in accordance with 314 CMR 2.06. Said notice shall state an authorization is under consideration by the Department, and indicate the Department's tentative determination. The applicant shall have the burden of justifying the authorization. Any authorization granted pursuant to 314 CMR 4.04 shall not extend beyond the expiration date of the permit.

(d) A discharge exempted from the permit requirement by 314 CMR 3.05(4) (discharge necessary to abate an imminent hazard) may be exempted from 314 CMR 4.04(5) by decision of the Department.

(e) A new or increased discharge specifically required as part of an enforcement order issued by the Department in order to improve existing water quality or prevent existing water quality from deteriorating may be exempted from 314 CMR 4.04(5) by decision of the Department.

(6) The Department applies its Antidegradation Implementation Procedures to point source discharges subject to 314 CMR 4.00.

(7) Discharge Criteria. In addition to the other provisions of 314 CMR 4.00, any authorized Discharge shall be provided with a level of treatment equal to or exceeding the requirements of the Massachusetts Surface Water Discharge Permit Program (314 CMR 3.00). Before authorizing a discharge, all appropriate public participation and intergovernmental coordination shall be conducted in accordance with Permit Procedures (314 CMR 2.00).

Appendix B: Summary of the Nitrogen Concentrations for Quissett Harbor Embayment System.

(Excerpted from Howes et. al, 2012, pg. 69). Data means were calculated from sample results collected from 1993 – 2009

Subembayment	Monitoring Station	Mean	Standard Deviation (all data)	N	model min	model max	model average
Quissett Harbor (inner)	QH2	0.354	0.069	66	0.3514	0.3554	0.3537
Quissett Harbor (main)	QH1	0.302	0.055	61	0.2956	0.3119	0.3016

Appendix C: Stormwater Loading Information

Table C1: Quissett Harbor Embayment System- Estimation of N Loading Contribution from impervious areas within 200 foot buffer to estuarine waterbodies

Sub-embayment	Impervious Area in 200 ft buffer (acres)[1]	Total Impervious Area in Watershed (acres)	Total Watershed Area (acres)	% Impervious of Total Watershed Area	Impervious Area in 200ft buffer as Percentage of Total Watershed Impervious Area	MEP Total Unattenuated Subwatershed Impervious Load (kg/day)[2]	MEP Total Unattenuated Watershed Load (kg/day)	Impervious buffer (200ft) WLA (kg/day)[3]	Buffer area WLA as percentage of MEP Total Unattenuated Subwatershed Load[4]
Quissett Harbor Inner	3.50	18.8	158.09	11.9%	18.6%	0.15	1.92	0.02	0.96%
Quissett Harbor Main	1.80	16.8	260.02	6.5%	10.7%	0.10	1.46	0.01	0.46%

1- The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated from GIS. Due to the soils and geology of Cape Cod it is unlikely that runoff would be channeled as a point source directly to a waterbody from areas more than 200 feet away. Some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of the wasteload allocation (WLA) it was assumed that all impervious surfaces within 200 feet of the shoreline discharge directly to the waterbody.
2- This includes the unattenuated nitrogen loads from wastewater from septic systems, fertilizer, runoff from both natural and impervious surfaces, atmospheric deposition to freshwater waterbodies.
3- The impervious subwatershed buffer area (acres) divided by total impervious subwatershed area (acres) then multiplied by total impervious subwatershed load (kg/year).
4- The impervious subwatershed buffer area WLA (kg/day) divided by the total subwatershed load (kg/day) then multiplied by 100.

Appendix D: Quissett Harbor Total Nitrogen TMDL

Table D1: Summary of TMDL for the Quissett Harbor System – 1 Total Nitrogen TMDL

Waterbody Name	Segment ID	Segment Description	TMDL Type	TMDL (kg/Day)
Quissett Harbor	MA95-25	The semi-enclosed body of water landward of a line drawn between The Knob and Gansett Point, Falmouth.	Restoration	7.83